National Bureau of Standards

TECHNICAL NEWS BULLETIN

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Standards of Very Small Capacitance

In response to requests from manufacturers and users of electron tubes, the National Bureau of Standards has established standards and equipment for testing and certifying small fixed standards of capacitance ranging in value from 100 down to 0.001 micromicrofarads. This work, under the direction of Dr. Charles Moon, has involved the development of a series of primary reference standards and the construction of several fixed secondary standards and variable capacitors. For values below 0.1 $\mu\mu$f, a new type of primary standard capacitor has been designed, utilizing a principle that makes practical the construction of units having a capacitance as small as may be desired.

The acceptance of many types of electron tubes by the research laboratories of the Armed Services, as well as by the manufacturers of electronic equipment, is based upon measurement of interelectrode capacitance. Lack of standardization in capacity measuring equipment has, in many cases, resulted in losses due to rejection by the purchaser of tubes whose interelectrode capacitance was not within the tolerance limits for acceptable performance. The result has been a demand on the part of industrial and Government laboratories for secondary reference standards of small capacitance. Such standards may be used in checking the calibration of bridges and test sets, which in turn are used to measure interelectrode capacitance. As secondary reference standards employed by the testing laboratories must be compared with known standards, the National Bureau of Standards was requested to establish and maintain a group of primary capacitance standards over the required range.

The capacitance values of several small capacitors have been determined at the Bureau by a process of stepping down or of subdivision from larger units, which are ordinarily measured by well-known bridge methods in terms of resistance and time. However, for capacitances of 5 $\mu\mu$f and lower it was considered desirable to check the accuracy of the subdivision by the use of absolute standards whose values could be computed from their mechanical dimensions.

In the range from 5 to 0.1 $\mu\mu$f the Kelvin guard-ring type of capacitor was used as a primary standard. In this device the high-voltage electrode is supported at a fixed distance from a smaller measuring electrode, which is surrounded by a guard ring to eliminate fringing. The larger electrode is connected to the high-voltage terminal of a bridge, and the measuring electrode and guard ring to the ground-potential terminals of the same instrument. Only that portion of the total flux from the high-voltage electrode that reaches the smaller electrode is measured by the bridge and is used in comparing the capacitor with a secondary standard. For precision work, an improved design was developed at the Bureau to permit accurate measurement of the necessary dimensions. In the precision design the guarded electrode and the guard ring, which are separated by a very small gap, as well as the high-voltage electrode, are flat and polished so that they can be readily tested by optical methods for parallelism.

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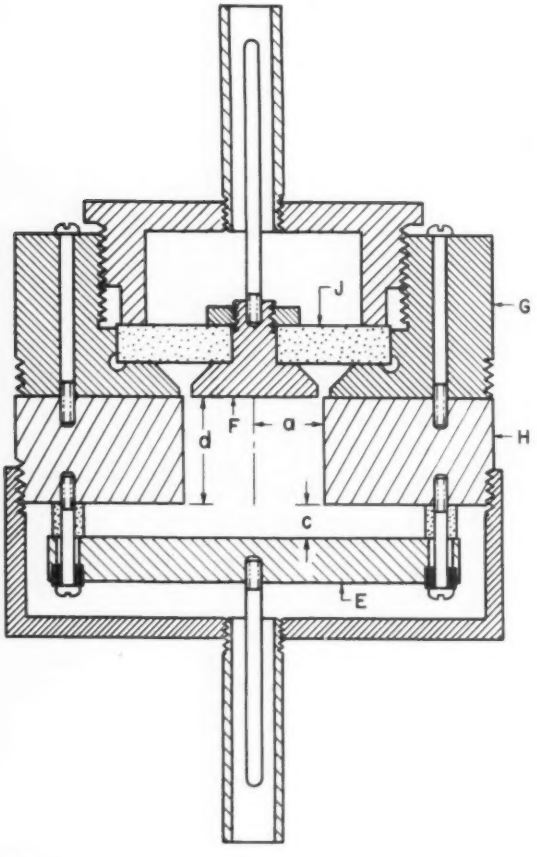
coplanarity, and symmetry. The guarded electrode, or "island", is rigidly and accurately centered in the guard ring by means of a Pyrex-glass collar held in position by firm pressure from a cup-shaped spring nut.

New Design for Lowest Range

For capacitance below 1 $\mu\mu$f, use of the classical guard-ring design requires either that the diameter of the island be quite small or that the separation of the plates be very large. For this reason, a new type of guarded-electrode capacitor was developed for the range from 0.1 down to 0.001 $\mu\mu$f on the basis of a design suggested by Dr. F. B. Silsbee, Chief of the Bureau's Division of Electricity and Optics. In the new capacitor, the guarded electrode, instead of being coplanar with the guard ring as in the Kelvin type, is placed at the bottom of a cylindrical well of fixed depth below the surface of the guard. Fringing occurs, depending on the depth of the well, so that only a fraction of the electric flux from the high-potential electrode reaches the measuring electrode. By increasing the depth of the well, the capacitance can be made as small as desired; at the same time the capacitor is of such dimensions that it can be constructed and measured accurately. The construction of the guarded plate and of the high-voltage electrode is identical with that of the guard-ring capacitor. Actually, the standard guard-ring type can be converted to the new design, by addition of a ring of suitable thickness with plane parallel sides and containing a central hole having a diameter equal to the diameter of the island plus the width of the gap.



Formulas for computing the capacitance of both types of capacitors have been derived by Dr. Chester Snow of the Bureau staff on the assumptions that the clearance between the island and the guard ring is infinitely small, that the edges of the hole in the guard ring are not rounded, and that the guard ring and voltage plates extend to infinity. However, measurements on an experimental model have shown that the clearance between the island and the guard ring can be as large as several thousandths of an inch without appreciably altering capacitance, and that the high-voltage plate need extend over the edge of the guard ring for a distance only three or four times the space between the high-voltage plate and the ring. A further increase in the size of the high-voltage electrode has no measurable effect but is undesirable because it increases the capacitance to ground.

A new type of guarded-electrode capacitor designed at the Bureau provides standards of very small capacitance. The high-voltage electrode, *E*, is held at a fixed distance from the measuring electrode, *F*, which is separated by a small gap from guard ring, *G*. Increases in thickness of the additional guard *H*, by reducing the flux to *F*, decrease the measured capacitance to as low values as may be desired.

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William C. Foster, *Acting Secretary*
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E. U. Condon, *Director*

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Contents

In addition to the primary standards, several secondary standards have been built. One of these, which is useful in comparing the primary standards with those submitted for test, is a decade of novel construction having two units of 0.1 $\mu\mu$f, two units of 0.2 $\mu\mu$f, and one unit of 0.4 $\mu\mu$f. Each unit of the decade consists of a pair of plates, insulated from the housing by mica insulation, together with a metallic blade that is connected to the housing. The individual units are switched out of the circuit by sliding the metallic blades between them. This completely isolates one terminal from the other, making the capacitance of the unit zero. The capacitance of each unit may be adjusted within very close limits by means of a vernier screw that controls the effective distance between plates. The units were adjusted at the Bureau to be equal or exact multiples of each other within the limits of sensitivity of a bridge and have held this adjustment for more than a year.

Primary standards of capacitance from one-tenth down to one-thousandth micromicrofarad have been prepared using the Bureau's new guarded-electrode design: (left) Measuring electrode surrounded by guard ring; (center) additional guard for the measuring electrode (the thickness of this guard controls the capacitance); (right) high-voltage electrode.

Zinc-Anode Protection In Dry Cells

During the war it was found that unused dry cells deteriorate rapidly in the tropics, with a resultant decrease in electrical output. One of the reasons for this failure under storage in extreme heat is the increased rate of corrosion of the zinc electrode. As the zinc electrode also corrodes at normal temperatures of 18° to 30° C, it is common practice either to amalgamate the zinc or to use chromate films to curtail this corrosion. However, at higher temperatures neither of these methods is adequate. C. K. Morehouse, W. J. Hamer, and G. W. Vinal of the Bureau's electrochemistry laboratory therefore undertook an investigation seeking more effective substitutes for mercury and chromate.[1] Attention was given to both inorganic and organic inhibitors and to modifications of the paste wall of the dry cell, which might increase its inhibiting characteristics.

The common dry cell consists essentially of a zinc container, which also serves as the negative electrode; a central carbon electrode surrounded by a core or bobbin of manganese dioxide mixed with acetylene black; and a paste-wall separator, usually made of starch-flour gel, which lines the container. An electrolyte of saturated ammonium chloride with a low concentration of zinc chloride is generally used in the bobbin.

The reactions occurring in a dry cell are of two types—the discharge reaction, which produces the available electrical energy, and the corrosion reaction or local action, from which no useful electrical energy is obtained. The first reaction may be written.[2]

$$Zn + 2MnO_2 \rightarrow ZnO.Mn_2O_3.$$

In the second reaction, hydrogen is formed as a result of galvanic action between local anodic and cathodic areas on the inner surface of the zinc case. At the anodic areas an atom of zinc goes into solution with the loss of two electrons:

$$Zn \rightleftarrows Zn^{++} + 2e,$$

and at the cathodic areas zinc ions react with ammonium chloride to form hydrogen gas:

$$Zn^{++} + 2NH_4Cl + 2e \rightarrow Zn(NH_3)_2Cl_2 + H_2.$$

The over-all corrosion reaction is then

$$Zn + 2NH_4Cl \rightarrow Zn(NH_3)_2Cl_2 + H_2.$$

This reaction may also be considered more simply as the discharge of hydrogen ions, that penetrate to the cathodic areas of the zinc container. Thus, the effectiveness of corrosion inhibitors may be determined by comparing the rate at which hydrogen is formed when the inhibitor is used with the rate observed for control experiments with no inhibitor.

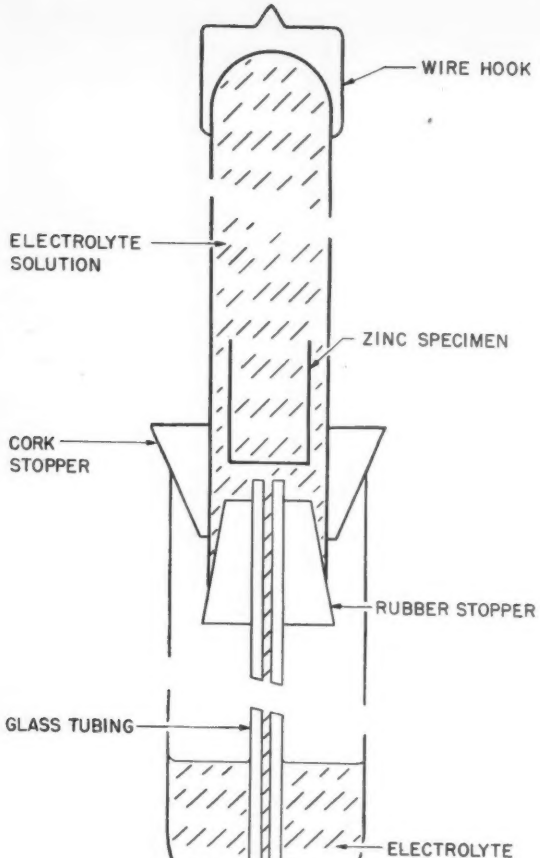
As it was necessary to study the inhibiting properties of many substances, a simple device for measuring the evolved hydrogen was employed. It consists of an inverted test tube closed by a rubber stopper, through which passes a capillary tube. Within the test tube is placed a sample of zinc, and the remainder of the tube, as well as the capillary, is completely filled with ammonium chloride electrolyte. The gas liberated at the zinc rises in the test tube, expelling an equal volume of electrolyte through the capillary. The test tube is weighed from day to day, and the volume of electrolyte expelled is calculated from the change in weight and the known density of the materials.

Inhibitors

In this way it was found that the corrosion of zinc in saturated ammonium chloride at 54° C—a temperature reached in storage in the tropics during the war—is curtailed by heterocyclic organic compounds having a second or third ring attached to the heterocyclic ring. For example, it was found that pyridine, piperidine,

[1] Clarence K. Morehouse, Walter J. Hamer, and George W. Vinal, Effect of inhibitors on the corrosion of zinc in dry-cell electrolytes, J. Research NBS **40**, 151 (1948) RP1863.

[2] H. F. McMurdie, D. N. Craig, and G. W. Vinal, Trans. Electrochem. Soc. **90**, 509 (1946).



The rate of evolution of hydrogen may be used as a measure of the corrosion of the zinc electrode in dry-cell electrolytes. Gas produced in the process expels an equal volume of electrolyte through the capillary. The volume of gas is then computed from the loss in weight of the tube.

alpha-picoline, and beta-picoline had little or no inhibiting action on corrosion of the zinc. These are heterocyclic compounds but consist of only one ring. On the other hand, it was observed that quinoline, paradipyridyl, quinaldine, beta-naphthoquinoline, and beta-naphthoquinaldine, all of which are heterocyclic compounds containing two or more rings, were effective in reducing the corrosion of zinc in dry-cell electrolytes.

Another class of organic compounds, those containing the carbonyl group (=C=O), was found to retard the corrosion of zinc under the conditions of the experiments. The best examples of heterocyclic and of aliphatic compounds of this type were furfural and crotonaldehyde, respectively.

Investigations of the paste wall showed that the flour constituent inhibited corrosion, whereas the starch constituent had little if any effect on corrosion of the inner surface of the zinc. It was found that the inhibiting properties of the paste wall could be enhanced by slightly increasing the percentage of flour or, more effectively, by using the gluten or protein fractions of wheat flour, namely, mesonin, 4° gliadin, −10° gliadin, or commercial unfractionated gliadin. These proteins may be applied as films on the inner surface of the zinc can or may be intimately mixed with the constituents of the paste wall.

Of the three types of inhibiting materials studied—heterocyclic organic compounds having two or more rings, compounds containing the carbonyl group, and wheat-flour proteins—the last named is the best in dry cells of the familiar flashlight type. The first two in general either react with the paste wall, decreasing its gel strength, or increase the internal resistance of the cell by forming a high-resistance film like a varnish on the surface of the zinc. In the case of wheat-flour proteins, neither of these phenomena occurs, and wheat-flour proteins also appear to increase the capacity of dry cells at moderate temperatures.[3]

[3] W. J. Hamer, Correlations of the gel strength of paste walls and the shelf-life of electric dry cells, J. Research NBS 40, 251 (1948) RP1870.

Stabilization of Austenitic Stainless Steel

Austenitic stainless steels, of the type usually referred to as 18-8 (18% chromium-8% nickel), are sometimes susceptible to intergranular embrittlement or corrosion. This type of corrosion is particularly pronounced in some 18-8 steels that have been subjected to moderately elevated temperatures—in the range 700 to 1,400° F—and are either simultaneously or subsequently subjected to corrosive conditions. Experience has shown that the susceptibility to embrittlement may be decreased or eliminated, that is, the steels may be stabilized against intergranular embrittlement, by the addition of titanium or columbium, usually in conjunction with a stabilizing heat treatment. A diversity of opinion has existed, however, as to the relative amounts of titanium or columbium necessary for effective stabilization of these steels, the injurious effect of carbon content, and the necessity for stabilizing heat treatments. Accordingly the National Bureau of Standards was requested by the Bureau of Aeronautics, Navy Department, to undertake a study of factors affecting the stabilization of the 18-8 type of steels.

Using both experimental and commercial steels made to a base analysis of 18 percent Cr and 10 percent Ni, the effect of variations in carbon content, in the ratios of columbium to carbon and of titanium to carbon, and of different heat treatments, was studied by Samuel J. Rosenberg and John H. Darr of the Bureau's thermal metallurgy laboratory.[4] The test ordinarily used to

[4] For further technical details, see Stabilization of austenitic stainless steel, by Samuel J. Rosenberg and John H. Darr, J. Research NBS 40, 321 (1948) RP1878.

Microstructures of two specimens of straight-carbon (0.09%) austenitic steel, sensitized 2 hours (*A*) and 2 days (*B*) respectively at 1,200° F., are indistinguishable. On exposure to boiling acid copper sulfate solution, however, specimen *A* suffered severe intergranular corrosion after 2 days (*C*, left) while specimen *B* showed no evidence of intergranular attack after 14 days (*C*, right).

induce susceptibility to intergranular attack consists of heating the steel for 2 hours at 1,200 to 1,250° F (this is termed the sensitizing treatment), followed by exposure for 2 days to a boiling solution consisting of 100 ml of H_2SO_4 (sp gr 1.84), 100 g of $CuSO_4.5H_2O$, and 900 ml of distilled water. The specimens are then dropped on a steel plate to note whether they have lost their metallic ring and are bent 180° over a rod whose diameter is equal to the thickness. The outer fibers are then examined for cracks. Steels that are immune to intergranular embrittlement have an unimpaired metallic ring and show no cracks after bending. Extremely susceptible steels lose their metallic ring completely and crumble on bending. In addition to these tests, all specimens studied at the Bureau were subjected to metallographic examination as well as a measurement of electrical resistivity, since intergranular corrosion increases this property considerably.

As part of the investigation, a variety of test conditions, some of them quite severe, were used to study susceptibility to intergranular attack. Specimens were sensitized at temperatures ranging from 840° to 1,380° F for periods up to 21 days, followed by exposure to the boiling acidified copper sulfate solution for 14 days. It was found that the most severe sensitizing treatment was 8 or 21 days at 1,020° F. Compared with this, the commonly specified treatment of 2 hours at 1,200 ° F is relatively mild.

Considering the steels that contained no stabilizing elements, the tests showed that all were vulnerable to intergranular attack. Decrease in carbon content, however, decreased the degree of vulnerability.

In the columbium- and titanium-bearing steels, carbon content within the range of 0.06 to 0.13 percent had no influence upon the resistance to intergranular attack, except as it influenced the Cb/C or Ti/C ratios. Steels varying in carbon content but having similar ratios of Cb/C or of Ti/C had approximately the same degree of susceptibility to intergranular attack regardless of the total carbon content. The steels showed greater resistance to attack when annealed at 1,800° F than when annealed at 1,975° F.

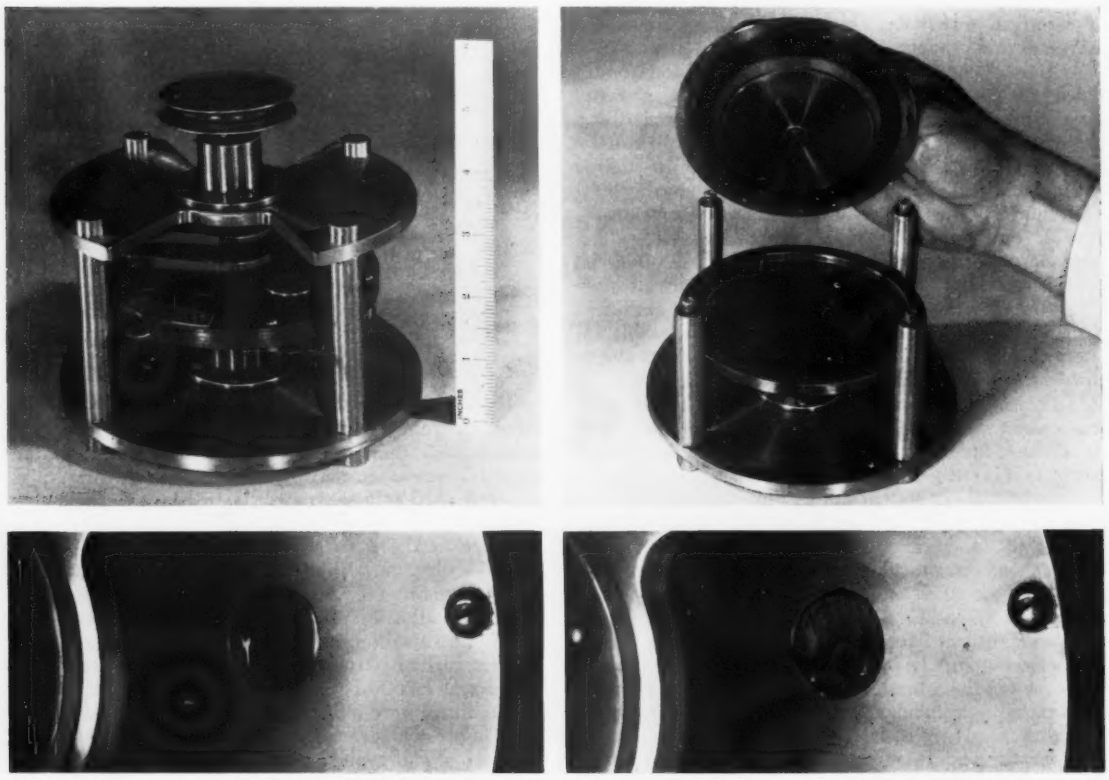
Stabilizing heat treatments at 1,600° F had a negligible effect upon the resistance to intergranular embrittlement of the columbium-treated steels, so that these steels carrying a sufficiently high ratio of Cb/C may be used without giving them a stabilizing heat treatment. However, the performance of the titanium-treated steels carrying the higher ratios of Ti/C was markedly improved by such treatments. When properly treated, substantially complete immunity to intergranular attack may be obtained with a minimum ratio of Cb/C=10 and Ti/C=5. For more certain immunity, these ratios should be 12 and 8, respectively.

The type of distribution of the precipitated carbides resulting from the sensitizing treatment was not an infallible indication of the resistance to intergranular embrittlement. Steels in which the carbides were distributed randomly were usually resistant to the intergranular attack. However, steels that contained carbides at the grain boundaries even though these carbides were distributed as a continuous network, either were or were not susceptible to intergranular attack, depending on the time-temperature relationship during sensitization. For example, two specimens of a straight carbon (0.09%) austenitic steel, one sensitized 2 hours at 1,200° F and the other 2 days at the same temperature, were indistinguishable on examination of their microstructure. Both showed a precipitation of carbides at the grain boundaries and on various slip planes. Their behavior after exposure to the boiling acidified copper sulfate, however, differed radically. The specimen that had been sensitized 2 hours suffered severe intergranular corrosion after 2 days' exposure, and that sensitized for 2 days showed no evidence whatever of intergranular attack even after 14 days.

Magnetic Fluid Clutch

A new type of electromagnetic clutch, having extensive applications and many unique features, has been developed at the National Bureau of Standards by Jacob Rabinow, Chief of the ordnance mechanics laboratory. The development of this clutch, which is based on Rabinow's discovery that frictional forces between solid surfaces and certain types of fluid media can be controlled by application of magnetic fields, was part of the work on the mechanical aspects of the high-speed electronic digital computers being built at the Bureau for the Office of the Chief of Ordnance, Department of the Army. Characterized by ease of control, high efficiency, smooth operation, long life, and simplicity of construction, the new magnetic fluid clutch is particularly suitable to applications in servo mechanisms, automatic machinery, automotive service, and many other fields where ease of control and constancy of characteristics are important. Mr. Rabinow has assigned all patent rights for the clutch to the U. S. Government.

The magnetic fluid clutch operates on the following basic principle: When the space between two parallel magnetic surfaces is filled with finely divided magnetic particles and a magnetic field is established between the two plates, the magnetic particles bind the plates together against movement parallel to their surfaces. The magnetic particles may be finely divided iron which, for most applications, is mixed with a liquid, such as oil, to prevent packing and to afford smoother operation of the clutch. When a portion of this mixture is acted on by a magnetic field, the iron particles are mutually attracted, bind together in the field, and the mixture seemingly "solidifies"—an effect readily demonstrated by lowering a small permanent magnet into a beaker of the iron-oil mixture. As the magnetic field can be produced by an electric current, a very simple means is thus obtained for the control of the binding force over a very wide range.



The first laboratory model of the new NBS magnetic fluid clutch (upper left) demonstrated successfully the principle that a magnetized fluid medium may be used to transmit torque from one movable plate to another, and that any degree of slippage between plates may be obtained by varying the magnetic flux in the fluid. The central chamber of the clutch (upper right), which is a very simple arrangement of driving and driven members (note the driving disk surrounded by magnet coil in upper plate), is filled with the mixture of iron powder and oil when in use. Close-ups of the filling hole in the central chamber show the appearance of the demagnetized fluid (lower left) and the arrangement of iron particles when magnetized (lower right).

Advantages of the Magnetic Fluid Clutch

Preliminary results at the Bureau indicate that the electromagnetic fluid clutch has numerous advantages over many other existing types. It is characterized by extreme smoothness of action, because all contacting surfaces, both of the plates and of the iron powder, are coated by a lubricant. The clutch is easy to control and requires but small amounts of electrical power. The control is extremely smooth from the minimum, which is determined by the viscous drag of the oil, to the maximum, which is controlled by the magnetic saturation of the iron. Unlike other electromagnetic clutches that follow a square law, wherein the torque is proportional to the square of the electric current, torque in the new clutch is proportional to the control current over a wide range of torque values. Hence, the clutch is particularly suitable to servo-mechanism applications where linearity and good control down to zero current are of primary importance.

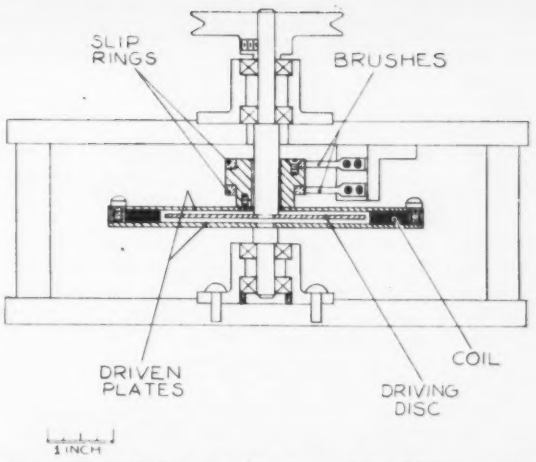
Another unusual and desirable feature found in some forms of the magnetic fluid clutch is that the value of static friction does not differ appreciably from the value of kinetic friction; hence no discontinuities in torque exist at the moment of initiation of slip. This feature is one of the principal reasons for smoothness of the clutch action, since chattering in an ordinary dry-friction clutch is due mainly to the difference between static and kinetic friction.

Because it has no axially moving parts, the clutch is extremely easy to build, consisting essentially of a driving and a driven member that do not change relative position, except in rotation. As slipping occurs only between extremely fine iron particles and between the iron particles and smooth face surfaces of the clutch, and as all the surfaces are lubricated, wear is practically nonexistent. Moreover, if any of the surfaces are worn off, the iron dust thus generated simply adds to the iron powder already in the oil mixture. The gaps, as normally employed, are fairly large; therefore, any such wear will have negligible effect. In the clutches tested at the Bureau, no wear has been noted, but because extensive life tests have not yet been run, it is not possible to rule out wear completely.

Design Factors

The design principles of the magnetic circuit of the clutch are no different from those used in all other electromagnetic machinery, with the possible exception that the value of the permeability of a suitable mixture of the carbonyl iron and oil is approximately 8 times that of air. A permeability of 8 implies that an iron powder gap of, say, 0.080 inch has the same reluctance as an air gap of 0.010 inch. This increased permeability of the gap greatly simplifies the design and construction of practical electromagnetic couplings of the type described. The permeability was measured by means of toroidal coils wound around lucite rings containing a known quantity of the magnetic mixture.

Higher permeabilities can be obtained by using less oil, larger particles, or aggregates of large and small particles, but it is doubtful that very much better values than those reported can be obtained with carbonyl *E* powder mixtures.



Current supplied to the slip rings of the NBS magnetic clutch energizes a coil in the disk-shaped central chamber, establishing a magnetic flux between the outer plates. This flux, acting in turn on the fluid in the enclosed space, produces a virtually solid mass. Any degree of slippage, or complete locking, between driving and driven members may be obtained by controlling the flux applied to the magnetic fluid.

One of the main considerations in the choice of gap dimensions is the effect of viscous drag. For example, in a clutch of the type suitable for automotive use, the viscous drag of the clutch plates when the magnet is deenergized must be kept to a minimum, while in an overload clutch this effect may be of no importance.

The magnetic clutches thus far built at the National Bureau of Standards are of a basic and simple form; that is, with the spacing of the plates fixed, though this construction has the disadvantage of producing appreciable viscous drag at high speeds when the clutch is deenergized. For one of the Bureau experimental clutches, the drag is approximately 1.0 lb-in. at 1,000 rpm and varies linearly with speed. This drag may be minimized in several ways, such as using a thinner mixture of iron and oil, using lighter oil, increasing the spacing between the plates, and, of course, driving the clutch at lower speeds. Mechanical devices that change the spacing of the plates automatically when the clutch is demagnetized can be employed, and the number of other expedients is unlimited. Normally this viscous drag is a small fraction of the clutch torque, and the heat generated can be readily dissipated. In regard to automobile applications, the low idling speed of gasoline engines is advantageous.

Consideration of the design of magnetic circuits leads to the following conclusions: The use of gaps in parallel, or single gaps of large area, entails large amounts of iron and small copper losses, while the use of gaps in series reduces the amount of iron but requires more excitation to overcome the total resultant gap length. Which method of attack is preferable depends

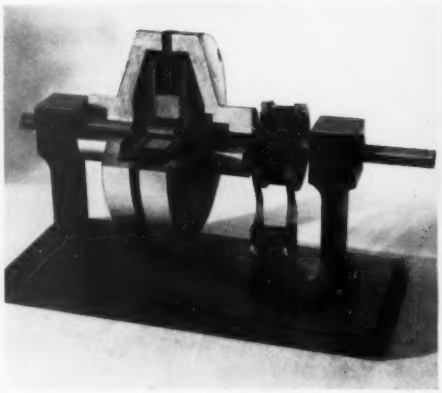
upon such factors as the availability of electrical power, considerations of weight, and size. Multiple-plate clutches can be designed so that the sets of plates are either in series or in parallel. Clutches that use the series gap arrangement are very compact, but heat dissipation presents special problems, particularly if such clutches are to be used continuously in a constantly slipping condition. Air or liquid cooling can, of course, be provided in any known manner.

Although the simplest designs employ a single circular coil, it is quite obvious that separate coils, spaced like the poles of an electrodynamic machine, may be used. The single coil is favored because of its simplicity of construction and excellent magnetic efficiency. Many other forms of magnetic circuits can be employed, depending on the materials used, results desired, cost, and other factors.

Where low inertia is required in the driven member, as in high speed servo work, it is desirable to make the exciting coil and magnetic iron a part of the driving member insofar as possible. Only a very thin member is then needed to pick up the torque. The thin driven plate, which normally is made of iron or other magnetic material so as not to introduce any unnecessary reluctance into the gap, may be made of various nonmagnetic materials as well. It was found that plates of such materials, when introduced into the magnetic gaps, experienced torque because of the attraction of iron particles from opposite sides of the plates. Work on this effect is still in process, but it has already been found that mesh or plates with perforations experience torques comparable to those obtained with iron plates. This effect is particularly important because, when a thin iron plate is used, there is always the possibility that mechanical eccentricities may be greatly exaggerated by the magnetic pull and the plate deformed sufficiently to contact one or the other of the magnetic surfaces. This type of unbalance of the magnetic pulls is well known to designers of rotating electrical machinery, and similar difficulties with bearings and shaft thicknesses, for example, may be experienced in the magnetic fluid clutches. By using nonmagnetic materials this difficulty is obviated.

Another problem that arises in connection with these clutches is that of sealing the oil-iron mixture in its compartment. There are two separate places where such sealing is generally required. One is the point where the shaft supporting the internal member leaves the assembly, and the second, if an internal coil is used, is the point at which the leads are brought out. Good results have been obtained by using rubber "O" rings at the shaft bearing, but there is no doubt that other types of packing can be employed successfully. If there is danger of the iron particles getting into ball bearings, it may be desirable to add a magnetic lock beyond the oil seal to trap any particles of iron that get through the seal. The oil that passes beyond this point would then be clean and should have no harmful effect on the bearings. Such a magnetic lock may consist of a permanent magnet ring flanked by two iron washers.

Generally speaking, it appears advisable to place the electrical winding inside the clutch for several reasons:



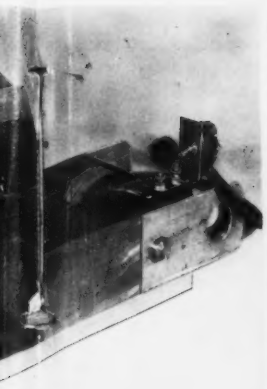
Preliminary experiments with a magnetic fluid consisting of fine iron pow ties that led to development of the magnetic fluid clutch. When acted up mixture in the magnetic field "solidifies" (upper left); laboratory tests wit the pull that could be sustained (upper right) by a 2-inch squa e plate. of clutch (lower left) and two small clutches suitable for servo work ((lower center). One of the clutches, locked to the frame, serves s a brak

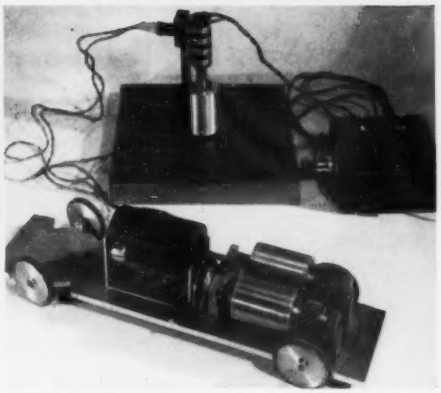
This placement reduces the amount of wire needed; it puts the torque surfaces at the maximum radius; it permits better dissipation of heat generated by the friction surfaces; and it reduces the over-all size and inertia of the clutch. There may, however, be times when these considerations are not important, but when seals present difficulties, particularly in the case of very thin shafts, the coils may be placed on the outside of the friction surfaces.

It is also possible to make the energizing coil completely separate from the clutch so that the coil is not revolved but transmits the magneto-motive force to the working faces through short air gaps. This can be accomplished at some loss of electrical efficiency and appears suitable only for very small sizes, where the power demands are low and the simplification is justified.

When an electromagnetic fluid clutch is used as a brake, slip rings are not necessary.

First experiments performed at the Bureau consisted of taking the field structure of an ordinary small 2-pole motor, replacing the armature with a cylindrical iron





fine iron powder suspended in oil emphasized the desirable proper- When acted upon by a small permanent magnet, that portion of the atory tests with specially designed apparatus (upper center) indicated square plate. Experimental designs included a multiple-disk type servo work (lower right) that were built into a midget auto bus rves as a brake.

rotor, and dropping the whole assembly into a beaker containing the iron-oil mixture. Voltage was then applied to the field windings and the locking torque on the rotor was examined. The torque was so great in this test that it appeared that the bearings had "frozen" or that the rotor shaft had bent out of shape, although subsequent tests showed this not to be the case. A simple flat plate model, constructed to determine the presence or absence of magnetic shear effect, was used for most of the experimental work at the Bureau. The bearings are external to the oil mixture, and, by using a vertical shaft, oil seals and their attendant friction are eliminated. The results indicated that the first experiments with the motor frame were quite valid in that large torques were no doubt due to the small gap present.

This motor was later remodeled and used with several sizes of rotors to determine effects of gap length, current, and speed on the resulting torque. In order to minimize the residual magnetic effects, the cylindrical rotors were made of 47-percent nickel steel. This construction is suitable for direct-current operation, and laminated disk construction would be more suitable for alternating-current use. When alternating currents are used to energize the model, the torques are somewhat lower.

Various experiments were performed with the flat plate clutch, the magnetic components of which are made of 47-percent nickel steel. The inner driving plate is a disk 0.062 inch thick by 3 inches in diameter and the iron-oil gap on each side of the disk is 0.062 inch. The coil consists of approximately 200 turns of No. 28 wire with a direct-current resistance of 15 ohms. In the design of this clutch, no effort was made to obtain an efficient magnetic circuit, since the gap area is large relative to the cross section of the magnetic material surrounding each side of the coil.

Experimental Results

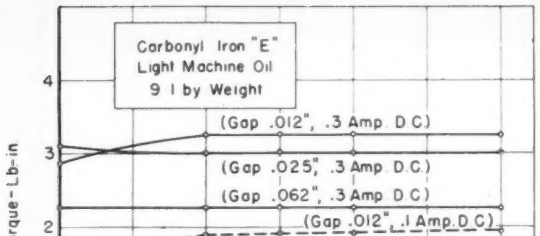
Tests on this clutch indicate that the static friction is not appreciably different from the friction obtained under conditions of slip. The relation between exciting current and torque is practically linear through zero. The clutch does not appear to obey the square law as is generally expected in magnetic devices. The reasons for this are not clearly understood. In one experiment with the flat-plate clutch, the torque was measured on a spring scale attached to a point on the periphery of the driven plates by means of a thin cable. It was found that when the clutch was driven by the electric motor the pointer on the scale remained completely steady, indicating that the value of the torque did not drop with the increase in speed, an effect quite common in dry friction clutches and one which usually results in considerable instability under similar conditions of test. As may be expected, the clutch heated up appreciably during each run because of the energy dissipated in friction; this resulted in a lowering of the viscosity of the oil and a slight change in torque.

Determination of the type of liquid to use as a vehicle is based on such factors as sealing, ability to withstand high and low temperatures, chemical stability, and availability.

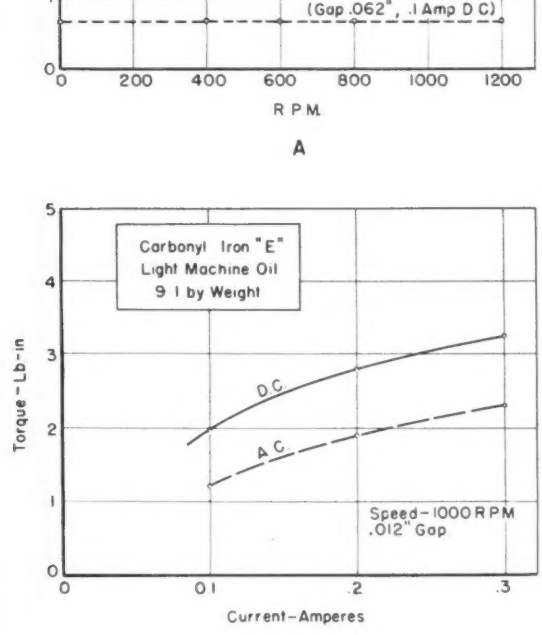
Typical results of tests on different types of iron and various proportions of iron and oil in the mixture are shown in the accompanying table. The behavior of the iron-oil mixture when magnetized and demagnetized

Torque of 3-inch disk clutch for various magnetic powder mixtures

Powder	Liquid	Proportions by weight		Torque for 1 amp direct current
		Powder	Oil	
				lb-in.
Carbonyl iron "*E*"	Light machine oil	5	1	7.7
Do	do	4	1	5.7
Do	do	3	1	5.5
Do	do	2	1	4.5
Do	do	1	1	2.3
Do	Silicone "*DC* 500"	10	1	8.0
Do	do	2	1	4.7
Carbonyl iron "*SF*"	Light machine oil	4	1	4.3
Stainless-steel flakes	do	3	1	3.3
Hydrogen reduced iron	do	1.5	1	2.3
Magnetic iron oxide	do	1.7	1	1.1



A



B

Performance curves of 1-inch by 1¼-inch-cylinder magnetic fluid clutch: *A*, torque for various gaps, *B*, torques for alternating and direct currents.

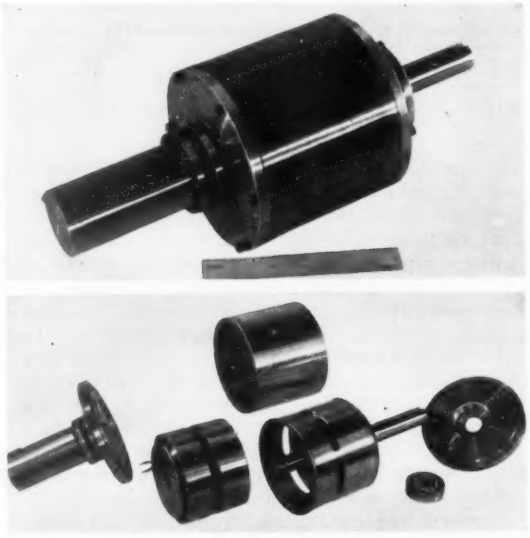
may be visually examined through one of the filling holes of the flat plate clutch. The liquid, when unmagnetized, looks like a heavy gray oil but when magnetized and subjected to shearing by revolving the inner plate, the material assumes a striated appearance. When the plate is moved, it appears that most of the shearing action occurs at the surface of the plate, with appreciable rearrangement of particles. It has been suggested that different types of surfaces on the clutch plates may have interesting effects on the behavior of such clutches. Tests of these effects have not yet been made.

It has been found that in this particular clutch, a mixture of oil and carbonyl *E* iron, which is composed of particles with an average size of 8 microns, gave the best results. This may not be true of other clutches or other conditions of tests. When dry powder is used in the clutch, the torques are of the same order of magnitude as when mixed with oil, but an eccentricity or misalinement of plates results in erratic operation.

Since the speed of response is of paramount importance in servo mechanisms, the time of build-up and decay of torque was measured. This was done by means of a wire strain gage attached to the rim of the driven member. The input voltage was applied to one pen of a multichannel recorder, and the strain gage was made a part of a 60-cycle bridge, the output of which was applied to a second pen of the recorder. In most instances torque rose and decayed in approximately $\frac{1}{30}$ second, although in some of the tests, rise- and fall-times of the order of $\frac{1}{60}$ second were noted.

Following these experiments, two small clutches suitable for servo work were built into a model auto bus. In order to keep the construction simple, the coil was placed on the outside of the clutch proper. This construction required only one seal, achieved by using a small rubber "O" ring. The slip rings consist of copper wire wound in shallow grooves in a Bakelite drum. The wires were soldered together and turned in a lathe to approximately half their original thickness. The coils, wound of No. 42 enamel wire, have a resistance of approximately 12,000 ohms each. The magnetic circuit is made of 47-percent nickel steel as in the two previous cases, with gaps of 0.032 inch. It was found that a current of 8 milliamperes results in a torque of 2 lb-in. This is the value at the knee of the saturation curve, with a value of 3 lb-in. obtained with approximately 24 milliamperes. One of the clutches, locked to the frame, is used as a brake.

By controlling the current through the clutch and



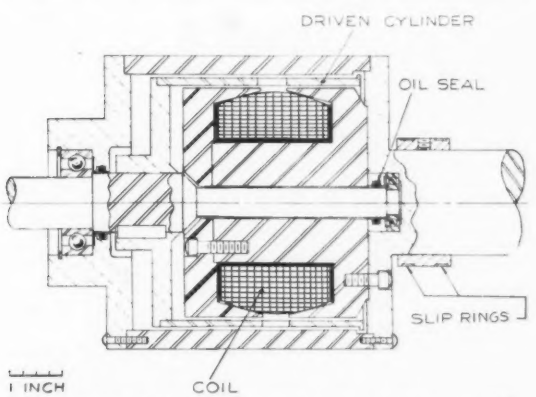
A magnetic fluid clutch (upper) suitable for automotive and machinery applications consists of the following parts (lower photo, left to right): Driving shaft attached to end-plate; coil and pole pieces, normally bolted to end-plate; inner member, attached to driven shaft; bearing; and end-plate. The assembly is completed by the outer shell shown above the other members.

brake, acceleration and deceleration can be easily controlled, and the car can be made to run smoothly at low speed. The brake action is also very smooth and positive.

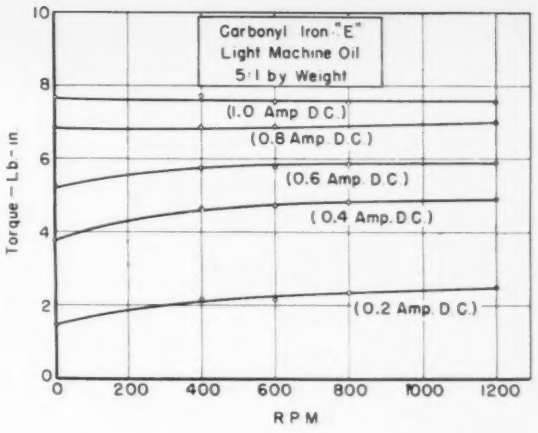
In order to study the effects of various surfaces, gap parameters, and other variables, it was decided to build a unit where such changes could be readily accomplished. It was constructed with a removable chamber in which various plates can be easily tested. The magnetic circuit is made of unannealed cold-rolled steel, resulting in large values of residual magnetism. This is overcome by means of a reversing switch provided in the electrical circuit. By using chambers with an internal width of $\frac{3}{16}$ inch, it was found that when a $\frac{1}{16}$-inch steel plate was inserted and the rest of the space filled with carbonyl *E* iron-oil mixture, the magnetic circuit reached the knee of its saturation curve with approximately 60 volts applied. The shear force on smooth plates $\frac{1}{16}$-inch thick reached a maximum value of 20 lb per sq in. of surface. The central plate is kept centered in the chamber by four brass pins. A rectangular plate gave values greater than those obtained later on circular plates due to the edge compression effects that it caused. When the magnet is energized, the iron-oil mixture becomes practically solid and can be held in any position without spilling. In a demonstration to show graphically and in easily appreciated terms the locking action of the magnetized iron-oil mixture, the weight of a person of average size was readily supported by the steel plate held by the energized mixture.

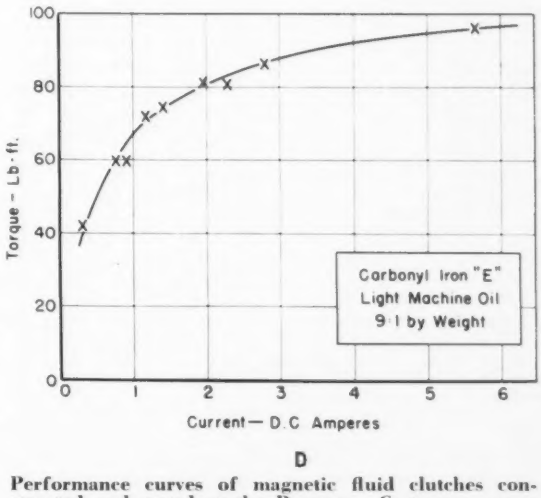
Basing the design on the results obtained with this fixture, a much larger clutch was built in the Bureau shops. The magnetic circuit is again of unannealed cold-rolled steel with the end plates made of dural. The coil has 600 turns of No. 18 wire with a total resistance of 3.5 ohms.

In order to keep inertia of the driven member low, most of the magnetic circuit iron and the coil were made part of the driving structure. The driven member consists of a $\frac{1}{16}$-inch thick cylinder mounted on a brass disk, which in turn is fastened to the driven shaft. Rubber "O" rings are used as seals. In the only test made so far, the clutch was mounted in a vise, and the output shaft was turned by the use of a 3-foot lever. It was found that in this particular design, the static friction at high torques was not equal to the torque when the clutch was slipping, the first time this was observed in such clutches. The reasons for the difference have not as yet been ascertained. The change of torque amounted to approximately 25 percent. However, the slipping torque, as observed on a spring scale driving the torque arm, appears to be very smooth. Again no square law effect is apparent in the relationship between torque and the magnetizing current. Additional tests on this clutch are underway.

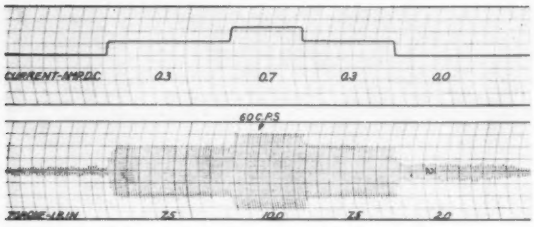


The magnetic fluid clutch, suited for use in automobiles and machinery, while only 6 inches in diameter and 6½ inches long, will transmit 40 hp at 3,000 rpm. A very thin driven member, all that is necessary to pick up the torque, makes this clutch also adaptable for such applications as high-speed servo work where low inertia is required in the driven member.





Performance curves of magnetic fluid clutches constructed and tested at the Bureau. *C*, torque versus speed, 3-inch-disk clutch (as used in early experimental model); *D*, torque of 6-inch-cylinder clutch (suitable for automotive and machinery applications).



Time-response curves of the 3-inch disk clutch compare the time of build-up and decay of torque with the input current. In this test torque rose and decayed in approximately $\frac{1}{30}$ second, although in some instances rise- and fall-times of the order of $\frac{1}{60}$ second were noted.

Applications of the Magnetic Fluid Clutch

The results obtained in the Bureau's experiments on the several forms of the magnetic fluid clutch suggest many possible uses for the new electromagnetic device. The automotive application is, of course, the most obvious one. Unlike fluid couplings of the type now common in automobiles, the clutch is not a speed-sensitive device; if the load is below the slipping torque of the clutch, no slippage occurs, and the mechanical efficiency of the clutch is 100 percent. The feature that particularly adapts the new clutch to automobile use is its easy controllability, which makes it especially attractive for use in automatic transmissions where permanently engaged gear trains are clutched in and out, depending upon the speed ratio required. Since the amounts of electrical power required to control the magnetic clutch are small, it is a simple matter to interlock the electrical circuits with the speed, throttle setting, and power demands.

The field where these new clutches are expected to find their main application, however, is in servo mechanisms. Here friction clutches have been used, but their lack of smoothness, the changes in characteristics caused by wear, their nonlinearity, and the poor reproducibility of results have given rise to great difficulties. The new clutch should go far toward solving such problems. Although servo mechanisms can be operated by variable-speed motors, hydraulic transmission, and many other means, clutches and brakes have the very great advantage of low inertia-to-torque ratios. Electromagnetic clutches are particularly adaptable to serve as the final elements of electromechanical amplifiers.

It was found by experiment that the nature of the oil used in the magnetic fluid clutch has relatively little bearing on the performance; hence silicone liquids may be employed with excellent results, enabling the clutch to operate at very low and very high temperatures, a consideration of great importance in military applications.

Another broad field of applications is in constant-torque and overload devices where the clutch need never be de-energized. Permanent magnet clutches are particularly useful for such service.

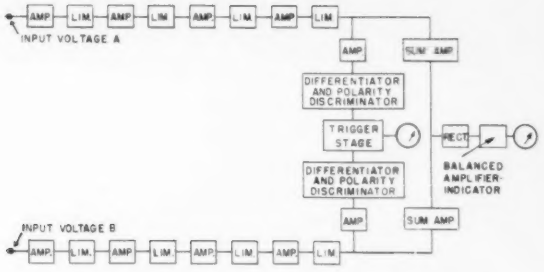
Improved Electronic Phase Meter

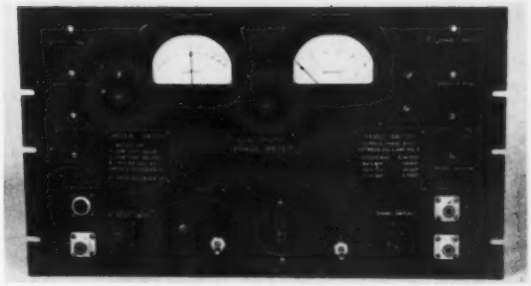
An improved electronic phase meter having significant advantages over previous instruments of this type has been developed by E. F. Florman and A. Tait of the Bureau's Radio Division, in connection with studies of radio wave propagation. The new instrument, which is designed for a frequency range of 100 to 5,000 cycles per second, reads and records directly the phase angle between two sinusoidal voltages having a variation of 1 to 30 volts. The two input voltages are first converted to square waves through two separate channels of amplifier-limiters. A direct comparison of the square waves then gives a measure of the phase difference between the original voltages. Two methods of comparing the square waves are employed. One involves their direct addition in a circuit having two tubes with a common plate resistor, and in the other method the square waves are used to produce voltage spikes that control a trigger-type phase indicating circuit.

Intensive studies of low-frequency propagation paths are now being made at the Bureau to obtain quantitative basic information on the propagation factors that limit the ultimate attainable accuracy of any low-frequency radio navigation system. Such information should be of value in choosing a radio-navigation system for a specific purpose and, ultimately, in the choice of a practical world-wide system. In this work, differential phase changes caused by changes in the propagation medium over the paths traversed are studied by analysis of the relative phases of incoming waves received at two separate collectors. It was, therefore, necessary to obtain a phase meter capable of reliable results over the frequency range under investigation. However, it was found that available instruments of this type did not operate satisfactorily over the necessary ranges of voltages and frequencies and were rather unstable during extended periods of observation. The Bureau therefore developed an electronic phase meter for this use.

To insure stability in the receivers, as well as in the phase measuring instrument itself, it was decided to obtain an audio-frequency beat note at each collector and to compare the phases by means of an audio-frequency phase meter. The resulting instrument has proved to be very stable over long periods, as well as sensitive and reliable over a wide range of voltages. It is thus well adapted to serve as standard test equipment in industrial laboratories. Other possible applications include use in electronic distance measuring devices for surveying; altitude determination for aircraft; navigation systems depending on phase changes; studies of distortion in telephone cables; and measurement of the phase characteristics of transmission lines, filters, and transformers.

The phase meter developed at the Bureau consists of the two channels of cascaded amplifiers and limiters





An improved electronic phase meter designed at the Bureau measures the phase difference between two sinusoidal voltages. Input voltages are first converted to square waves by passage through separate channels of cascaded amplifiers and limiters (block diagram, left) and then applied, for comparison, to two different phase indicators, designated "sum" and "trigger." The former involves the direct addition of the square waves in a circuit having two tubes with a common plate resistor, and in the latter the square waves produce voltage spikes that control a trigger-type phase indicating circuit.

followed by two types of phase-indicating circuits. The two indicating circuits—known as the "sum" indicator and the "trigger" indicator—are based upon different principles in order to afford a direct comparison between them.

Effectively, the sum indicator functions by measuring the algebraic sum of the square waves appearing in the similar channels. This algebraic sum is proportional to the phase angle between the input voltages but is ambiguous about the 180-degree value, that is, the same dial reading is obtained for a phase difference of 170° as for a phase difference of 190°. The two square waves are each applied to the grids of separate tubes having a common plate resistor. The average current through this resistor is directly proportional to the phase angle between the square waves and is therefore proportional to the phase angle between the sinusoidal input voltages. This average value is obtained, by means of a diode rectifier and a balanced amplifier, on a milliammeter that acts as the phase indicator. The balanced amplifier circuit is arranged by means of proper shunts to give three ranges of phase-angle measurements: 180° to 135° or 225°, 180° to 90° or 270°, and 180° to 0° or 360°.

In the trigger indicator system, the square waves are first applied to the grids of amplifier tubes, and the amplified square waves are then differentiated in the plate circuits of these tubes. The resultant voltage spikes, which occur at the instant of rise or fall of the square waves, are applied to a diode polarity-discriminator tube, which suppresses the positive voltage spikes and passes the negative impulses to the grids of a modified Eccles-Jordan trigger circuit. The trigger circuit is so connected that when a negative impulse is applied to the grid of one of a pair of tubes, that tube cuts off, simultaneously firing the other tube. In turn, when the second tube receives a negative pulse, it cuts off, again firing the first tube. As a result of this process, the average current flowing in the plate circuit of the trigger tubes is a measure of the time interval between voltage spikes from the two channels of the phase meter, and this time interval corresponds to the relative phase of the sinusoidal input voltages. Both recording and indicating milliammeters are used with shunts to give three ranges of phase-angle measurements: 130° to 230°, 80° to 280°, and 0° to 360°. The phase-angle readings in the trigger indicating circuit are unambiguous, but the circuit is inherently unstable for phase angles in the neighborhood of 0 and 360 degrees, since here the order of firing of the tubes alternates irregularly. However, exact values may be obtained for phase angles in this region by use of the sum indicator.

The new instrument reads and records phase differences with a sensitivity of 0.5 degree. In a series of tests at the National Bureau of Standards, the curve of phase-meter reading versus phase was found to be linear within one degree over a range of input frequencies from 100 to 5,000 cycles per second. For very rapid changes in the amplitudes of input voltages from 1 to 20 volts, the readings showed a phase change of but 1.0 degree. Observations were independent of frequency from 100 to 5,000 cycles. In this frequency range, for input voltages from 2 to 15 volts, the readings varied only ± 0.25 degree for a line-voltage variation of 100 to 120 volts. A 72-hour-stability test showed that the maximum drift after the first 15 minutes of warm-up was approximately ± 1.6 degrees, and the maximum rate of drift was 0.25 degree per hour. Throughout the tests, the sum and trigger indicators agreed closely.

Tables of Bessel Functions

Of interest to nuclear technologists, as well as other design engineers and physicists, is the new NBS publication presenting extensive tables of the Bessel functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$, and $K_1(x)$ in the region between 0 and 1. These tables, prepared by the Bureau, constitute the first publication in the new Applied Mathematics Series, which will include mathematical tables, manuals, and studies by the National Applied Mathematics Laboratories of the Bureau.

Because of the frequent need for numerical values of the Bessel functions in many physics and engineering problems, the tables have been computed at much

closer intervals than previous tabulations of these functions, thus enabling the user to obtain almost the full accuracy of the table, over most of the range, by linear interpolation. Specifically, the tables give the values of $Y_0(x)$ and $Y_1(x)$ with first and second differences for $x=0(0.0001)0.05(0.001)1$ and the values of $K_0(x)$ and $K_1(x)$ with first and second differences for $x=0(0.0001)0.03(0.001)1$.

Applied Mathematics Series 1. Tables of the Bessel functions $Y_0(x), Y_1(x), K_0(x), K_1(x) 0 \leqq x \leqq 1$, may be obtained only from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 35 cents a copy.

Selected Properties of Hydrocarbons

One of the bulwarks of all technical and scientific research is the collection and critical appraisal of the pertinent information already available. One type of such information that is required by laboratories in industry and science comprises selected values of the fundamental physical constants and of the properties of the chemical substances. Many advantages result from having such fundamental work performed systematically and consistently in a cooperative program, by a full-time staff of experts, rather than incidentally and sporadically by workers in different laboratories. In addition to the obvious advantages of producing a complete, accurate, and self-consistent set of values of constants and properties, such an arrangement results in a considerable saving in over-all cost and manpower.

The Bureau's Research Associate Plan makes it possible for an industry to join with the National Bureau of Standards in the prosecution of a fundamental research program of mutual benefit and in the public interest. Research investigations in the petroleum, rubber, and chemical industries depend heavily upon fundamental data on the physical and thermodynamic properties of hydrocarbons. In 1941, the National Bureau of Standards proposed to the American Petroleum Institute that the two organizations cooperate in the compilation of tables of selected values of properties of hydrocarbons. The proposal was approved, and this work was begun in 1942, as the American Petroleum Institute Research Project 44. The Advisory Committee for the Project has from the beginning consisted of: W. E. Kuhn (chairman), Otto Beeck, Gustav Egloff, and S. S. Kurtz, Jr. As of January 1, 1948, the research staff of the project consists of the following: At the National Bureau of Standards, M. B. Epstein, Joan P. Ebert, Marie T. Lynch, Mary F. Helm, and Rita M. Braun, under the direction of F. D. Rossini; at the University of California, N. K. Freeman and W. Weltner, Jr., under the direction of K. S. Pitzer.

With regard to the physical and thermodynamic properties of hydrocarbons and closely related compounds, the aims of the project are as follows: (1) To examine all the pertinent original data in the literature and all available unpublished data and to appraise them critically; (2) to correlate values of given properties with temperature, pressure, molecular structure, and other variables, as appropriate; (3) to make original calculations of thermodynamic and physical properties, as necessary; (4) to select and tabulate "best" values of the properties; (5) to prepare the selected values in a convenient, usable form for prompt distribution; (6) to prepare the original calculations, analyses, and correlations in a form suitable for publication; and (7) to keep the tables of selected values of properties up to date by revision at appropriate intervals.

The properties under investigation include boiling point; refractive index; density and specific gravity; freezing point; molecular volume; molecular and specific refraction; specific dispersion; refractivity intercept; viscosity; critical constants; PVT relations; vapor pressures; heat and entropy of vaporization; heat of combustion; heat content; free energy function; entropy; heat capacity; heat of formation; free energy of formation; equilibrium constant of formation; heat and entropy of fusion; cryoscopic constants; and heat of transition.

In addition to the compilation of critically selected values of the physical and thermodynamic properties, the American Petroleum Institute Research Project 44 has also performed the service of collecting (from cooperating industrial, university, and Government laboratories) and distributing, on standard forms, infrared, ultraviolet, Raman, and mass spectral data.

As of January 1, 1948, the Project has issued, in loose-leaf form, 398 pages of numerical data on the physical and thermodynamic properties, 3 pages of values of fundamental constants, 7 pages of values of conversion factors, 1 page of equations, and 16 pages of molecular weights. The tables are being extended to cover additional properties and compounds as rapidly as the resources permit. All the numerical values appearing in the tables have been critically selected, and the project assumes complete responsibility for the reliability of the selected values within the indicated limits of uncertainty.

The Project has also issued, in loose-leaf form, 79 pages of specific references and 26 pages of general references. These references cover all data, published and unpublished, used to obtain the selected values given in the tables.

A total of 677 infrared spectrograms, together with 13 descriptions of spectrographs, and 188 ultraviolet spectrograms have appeared in the catalogs of spectrographs. The ultraviolet spectrograms cover 272 different compounds, of which 230 are hydrocarbons and 42 are nonhydrocarbons; and the infrared 105 different compounds, of which 73 are hydrocarbons and 32 are nonhydrocarbons. A table of wavelengths, corresponding to maxima in absorption, is usually given on the reverse side of the spectrogram. Contributions of infrared and ultraviolet spectral data have been made by

many cooperating laboratories, each of which in turn assumes responsibility for the reliability of their data.

The collection and distribution of both Raman and mass spectral data have also been started. Fifty-six tables of mass spectral data, covering as many hydrocarbons, have been issued up to January 1, 1948, with more in process.

The importance of the work of the API Research Project 44 lies principally in its provision of a complete, accurate, and self-consistent set of values of the physical and thermodynamic properties of hydrocarbons. Users of the tables may assume that the values selected represent the best information available to the Project at the time of issue. Some of the uses to which the tables have been put include identification of hydrocarbons; evaluation of the data of analytical distillations; setting up correlations of physical properties or combinations of physical properties, for analyzing mixtures of hydrocarbons by type; evaluation of the purity of hydrocarbons from measurements of freezing points; evaluation of heats of combustion (which are given in cal/mole, cal/g, and Btu/lb); calculation of heat balances for industrial processes (for engineering use, these data are also given in cal/g deg C and in Btu/lb deg F); evaluation of equilibrium constants for given reactions in industrial processes, such as those of hydrogenation, dehydrogenation, dimerization, cyclization, isomerization, alkylation, and cracking.

The importance of using reliable values for thermodynamic properties is illustrated by the fact that a change of about 3 kilocalories per mole in the heat of a given reaction performed at room temperature will change the value of the equilibrium constant by a factor of approximately 200.

Since the beginning of the work, the tables of selected values of properties and the spectral data have been, and will continue to be, issued in loose leaf form, monthly as compiled. The distribution of this material is in accordance with the following plan: (1) Copies of tables and spectrograms are supplied to all U. S. Government laboratories having a proper need for them, at no cost, on application to the National Bureau of Standards; (2) one set of the tables and spectrograms is supplied gratis to each University Department of Chemistry, Physics, and Engineering, and to the nonprofit research institutions, with the compliments of the American Petroleum Institute and the National Bureau of Standards, on application to the National Bureau of Standards; (3) up to 10 copies each of the tables and spectrograms are supplied gratis to each of the supporters of the research fund of the American Petroleum Institute, on application to the Institute; (4) additional sets of the existing data, as well as new material as issued, may be obtained by individual research workers, and by laboratories in industry, research institutions, and universities, from the American Petroleum Institute, attention of Mr. D. V. Stroop, 50 West 50th Street, New York, N. Y., *in complete sets only*, at a cost of 3 cents per sheet for the tables of properties and 5 cents per sheet for the spectral data.

A complete collection of the numerical tables issued by the Project up to May 31, 1947, together with the appropriate references to the literature, has been published in book form by the National Bureau of Standards. The bound volume, which contains 496 pages, is designated National Bureau of Standards Circular C461, Selected values of properties of hydrocarbons. NBS Circular C461 is available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at $2.75 a copy. The plan of issuing new tables in loose-leaf form, monthly as compiled, will in no way be affected by the preparation of this bound volume.

NBS Scientists

Philip L. Wormeley, Assistant Chief of the Bureau's Division of Organic and Fibrous Materials and Chief of the Section on Testing and Specifications, has retired after 37 years of service with the Bureau, and 44 with the Federal Government. Mr. Wormeley has contributed extensively to the fields of leather, rubber, and the development of Federal Specifications. In collaboration with laboratory associates, he did pioneer work on endurance and dynamometer tests for tires. He also investigated power losses in tires and effects of these power losses on fuel consumption.

Dr. Gordon M. Kline, Chief of the Organic Plastics Section, has been designated to succeed Mr. Wormeley as Assistant Chief of the Division. Dr. Kline is known for his research on airplane dopes, oxidation of sugar, polymerization of olefins, and especially organic plastics. He was one of the first American scientists to investigate the German plastics and chemical industries, even before the close of the war in Europe.

Dr. Robert D. Stiehler has been appointed Chief of the Testing and Specifications Section. Dr. Stiehler, who has conducted research on rubber in both industrial and Government laboratories, was instrumental in developing methods of quality control for synthetic rubber production in Government plants during the war.

Gas Calorimeter Tables

A revision of the Bureau's Gas calorimeter tables, designated NBS Circular C464, includes instructions for use of the water-flow calorimeter in measuring the heating value of fuel gases, as well as tables required for the necessary calculations and directions for their application.

The heating value—that is, the heat produced by combustion of unit volume—of a fuel gas is the property upon which its value to the purchaser depends. For this reason, a large number of laboratories maintained by public service commissions, producers, and consumers are regularly engaged in measuring the heating values of gases. One of the most widely used instruments for making such measurements in this country is a water-flow calorimeter of the Junkers type.

A number of years ago, the Bureau carried out an exhaustive investigation of water-flow calorimeters, in which it was found that this type of instrument can be used to measure heating values of gaseous fuels with sufficient accuracy for most purposes. However, it was also shown that for best results the calorimeter and

accessory apparatus must be correctly adjusted and operated, and the proper procedure followed in the computations, including the application of numerous corrections to the observed heating value. Directions for adjustment and operation, and for calculations, have been published in a series of NBS circulars, which have been revised at intervals to reflect improved techniques and to give equal consideration to the various types of fuel gases that have come into use. For approximately 30 years, these publications have been widely used as laboratory handbooks in the field of gas calorimetry.

In Circular C464 there has been some change in notation and in the method of deriving equations for humidity corrections. This was done to avoid possible confusion arising from differences of notation and methods of presentation in the ASTM Tentative Method of Test for Calorific Value of Gaseous Fuels by the Water-Flow Calorimeter. Improved data that have appeared in recent years have also been used in the revision. Circular C464 is available only from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 15 cents a copy.

NBS Publications

Periodicals [5]

Journal of Research of the National Bureau of Standards, volume **40,** number 4, April 1948. (RP1871 to RP1878 inclusive).

Technical News Bulletin, volume **32,** number 4, April 1948. 10 cents.

CRPL–D44. Basic Radio Propagation Predictions for July 1948. Three months in advance. Issued April 1948. 10 cents.

Nonperiodical

Research Papers [5] [6]

RP1865. Measurement of water in gases by electrical conduction in a film of hygroscopic material and the use of pressure changes in calibration. Elmer R. Weaver and Ralph Riley. 25 cents.

RP1866. Electric quadrupole coupling of the nuclear spin with the rotation of a polar diatomic molecule in an external electric field. U. Fano. 15 cents.

RP1867. Preliminary study on portions of the systems Na_2O–CaO–Al_2O_3–Fe_2O_3 and Na_2O–CaO–Fe_2O_3–SiO_2. William R. Eubank and Robert H. Bogue. 15 cents.

RP1868. Theory and design of a cavity attenuator. J. J. Freeman. 15 cents.

RP1869. Theory of Wagner ground balance for alternating current bridges. Richard K. Cook. 10 cents.

RP1870. Correlations of the gel strength of paste walls and the shelf life ol electric dry cells. Walter J. Hamer. 15 cents.

Circulars [5]

C464. Gas calorimeter tables. Ralph S. Jessup and Elmer R. Weaver. (Supersedes C417.) 15 cents.

Commercial Standards [5]

CS125–47. Prefabricated homes. (Supersedes CS125–45.) 10 cents.

Simplified Practice Recommendations [5]

R10–47. Milk and cream bottles (Capacities, weights, dimensions, and finishes). (Supersedes R10–27). 10 cents.

Letter Circulars [7]

LC891. Publications relating to building codes and construction practice—home building—building material specifications—home maintenance. (Supersedes LC858).

LC892. Dry etching of glass. (Supersedes LC150).

LC893. Dental materials—publications by the staff of the National Bureau of Standards and research associates on dental materials. (Supersedes LC839).

LC894. Publications relating to accident prevention and safety. (Supersedes LC806).

LC584 (Supplement). Standard specifications for sieves.

Articles by Bureau Staff Members in Outside Publications [8]

Pure compounds from petroleum. F. D. Rossini. Analytical Chemistry (1155 Sixteenth Street NW, Washington 6, D. C.) **20,** 110 (1948).

The nucleus—Its structure and reactions. W. E. Shoupp and Hugh Odishaw. Electrical Engineering (500 Fifth Ave., New York 18, N. Y.) **67,** No. 2, 125 (1948).

What's happening on clothing sizes. Mansfield Lonie. Industrial Standardization (American Standards Association, 70 East 45th Street, New York, N. Y.) **19,** No. 1, 14 (1948).

Highlights of the development of reinforced concrete and study of bond. Arthur P. Clark. J. Am. Concrete Inst. (7400 Second Boulevard, Detroit 2, Mich.) **19,** No. 6, 437 (1948).

Fractionation and analysis of hydrocarbons by adsorption. Beveridge J. Mair. Annals New York Academy of Sciences (Central Park West at Seventy-ninth Street, New York 24, N. Y.) **49,** 218 (1948).

The surface area of some solid adsorbents of possible use in chromatography. Victor R. Dietz. Annals New York Academy of Sciences **49,** 315 (1948).

Plastics (part of a symposium on chemical engineering materials of construction). G. M. Kline. Industrial and Engineering Chemistry (1155 Sixteenth Street NW, Washington 6, D. C.) **39,** 1234 (1947).

Sorption of nitrogen and water vapor on textile fibers. J. W. Rowen and R. L. Blaine. Industrial and Engineering Chemistry **39,** 1659 (1947).

Reactivity ratios in diene and diene-vinyl copolymerization. L. A. Wall. Journal Polymer Science (Interscience Publishing Co. Inc., 215 Fourth Avenue, New York, N. Y.) **2,** 542 (1947).

Control of grain size in magnesium casting alloys. V. C. F. Holm and A. I. Krynitsky. The Foundry (1213 West Third Street, Cleveland, Ohio) **75,** No. 10, 81 (October 1947).

Fire tests of treated and untreated wood walls. Nolan D. Mitchell. Proc. Am. Wood Preservers Assn. (1427 I Street NW, Washington 5, D. C.) **43,** 353 (1947).

The measurement of high voltages. Francis M. Defandorf. J. Washington Acad. Sci. (% Harold A. Rehder, U. S. National Museum, Washington, D. C.) **38,** 33 (1948).

Standardization of the pH scale. Roger G. Bates and Edgar R. Smith. J. Washington Acad. of Sci. **38,** 61 (1948).

Definitions of pH scales. Roger G. Bates. Chemical Reviews (Mt. Royal & Guilford Avenues, Baltimore 2, Md.) **42,** 1 (1948).

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[5] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, $4.50 (foreign $5.50); Technical News Bulletin, $1.00 (foreign $1.35); Basic Radio Propagation Predictions, $1.00 (foreign $1.25). Single copy prices of publications are indicated in the lists.

[6] Reprints from March Journal of Research.

[7] Available on request from the National Bureau of Standards, Washington 25, D. C. Letter Circulars are prepared to answer specific inquiries addressed to the Bureau, and are sent only on request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.

[8] These publications are not available from the Government. Requests should be sent direct to the publishers.

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